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FOR PARTICLE AND NUCLEAR PHYSICS

OPERATED AS A JOINT VENTURE

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UNDER A CONTRIBUTION FROM THE
NATIONAL RESEARCH COUNCIL OF CANADA

OCTOBER 2001

The contributions on individual experiments in this report are outlines intended to demonstrate the extent of scientific activity at TRIUMF during the past year. The outlines are not publications and often contain preliminary results not intended, or not yet ready, for publication. Material from these reports should not be reproduced or quoted without permission from the authors.

ACCELERATOR TECHNOLOGY DIVISION

INTRODUCTION

As for the past few years, the ISAC project occupied most of the effort of the division during 2000. The mechanical engineering and design effort involved continuing work on the DRAGON spectrometer, drift tube linac (DTL) components, high energy beam transport (HEBT) line, further work on the ISAC target/ion source modules and target hall, and hot cell devices required for handling and servicing. The Design Office spent 71% of available hours on ISAC related work. These activities are described in more detail in the following pages and in the ISAC Project section.

There were a few non-ISAC projects which were supported, the largest being TWIST or Expt. 614 which is being mounted on the M13 secondary channel. The large solenoid magnet shield was designed and the contract let for machining of the 61 ton steel plates. This work was completed and the steel assembled around the superconducting solenoid magnet by the end of the year. There was also design work on the cradle to support the wire chamber planes and the magnet field measuring equipment for mapping the central field distribution. An even larger field mapper for the $G\emptyset$ experiment, which is to be carried out at Jefferson Laboratory, was assembled at TRIUMF and then sent to the University of Illinois where it is being commissioned. This work involved several trips to Illinois by a TRIUMF engineer.

For the CERN-LHC collaboration the assembly of large pulse forming network tanks (PFNs) began and this work, along with the ongoing saga of the twin-aperture quadrupole fabrication, is described in the CERN Collaboration section. The engineering group at the University of Victoria continued their work on the design of the large structure for mounting and rotating the HEC calorimeter modules into the ATLAS detector. Fabrication and testing of the signal feedthrough assembly also continued.

The Machine Shop coped with an ever increasing workload, also mainly on ISAC related fabrication jobs. This year, more than $1 million in work packages were sub-contracted to local fabrication shops through the Machine Shop. The Planning group provided coordinating and expediting services to ensure that important milestones were met throughout the year, and that other projects received a reasonable level of support to keep them going. A new, 5-axis, CNC milling machine was commissioned in the shop this year and several machinists took courses at BCIT on programming this machine.

ISAC also required a number of buildings and shielding structures which were designed and coordinated by the Building department. One of these structures was the electrically shielded room for housing the TUDA experiment electronics. The biomedical annex received a major renovation with offices and laboratory space for more than 20 μSR scientists created. Assistance was also given to the design and specification of the ISAC-II building.

The Electronics Services group provided support for the ISAC and CERN work and became heavily involved in producing electronics for the TWIST experiment. This work involved manufacture of the postamp modules, together with considerable cable manufacture. There was a significant increase in the demands for PC support and the new PC backup service was implemented.

The Electronics Development group continued their support of the ISAC control system design and implementation. This year there were additional requirements for the ISAC experiments including β-NMR and DRAGON. The VME data acquisition board developed for the CERN-LHC beam orbit system was successfully tested at CERN.

BEAM DYNAMICS

Three joint studies were begun with other laboratories this year, in addition to the TRIUMF-LHC collaboration. One, still involving CERN, concerned longitudinal simulations for the proposed Neutrino Factory proton accumulator and compressor rings. Another explored the feasibility of producing very short "micro-bunches" for the proposed $K_L \to \pi^0\nu\bar{\nu}$ experiment at the Brookhaven AGS. The third investigated the effectiveness of electron beam lenses for compensating space-charge effects in the Fermilab booster.

CERN Neutrino Factory Proton Driver

High-energy muons, stored in a decay ring with long straight sections, would provide a unique beam of high-energy neutrinos, enabling precise determination of several parameters of the neutrino mass matrix. CERN is studying such a Neutrino Factory to feed distant detectors at Grand Sasso, with muons produced by a 4 MW proton driver (PDAC), composed of a 2.2 GeV superconducting linac, accumulator and compressor rings. The intense proton beam could also provide a higher brilliance beam for LHC.

In support of this study, longitudinal beam dynamics simulations were begun in the spring, both for the accumulator, which collects 660 turns of H^- from the linac, and for the compressor, which rotates the bunches 90° in ≈7 turns; two variants of each machine have been studied. Enhancements were made to the LONG1D multi-turn injection algorithms to carry out these simulations, which have so far confirmed the feasibility of using high-transition-energy lattices. The high synchrotron frequency is instrumental in smoothing the accumulated distribution in longitudinal phase space.

Bunch rotation produces a large momentum spread and short bunches with large space-charge forces. Chromatic non-linearity becomes more important for large momenta, and a higher order expansion of the "slip factor", which relates increment in orbit period to that of momentum deviation, was introduced. Further, the dispersion function is distorted by transverse space-charge forces, making the momentum compaction factor dependent on the local charge density. This effect was also modelled, but the simulations did not reveal any related problems in either the accumulator or compressor.

Micro-Bunching at Brookhaven AGS

In support of a proposed measurement of the CP-violating decay $K_L \to \pi^0 \nu \bar{\nu}$ at the AGS, which requires very narrow 0.15 ns proton "micro-bunches" at 40 ns intervals to allow time-of-flight (TOF) discrimination from the overwhelming background of $K_L \to \pi^0 \pi^0$ decays, studies have begun as to whether the recently developed micro-bunching techniques for the slow-extracted beam can be refined sufficiently to meet this requirement.

Micro-bunching relies upon squeezing the debunched beam through the gap between empty buckets that are centred near the extraction radius. The betatron tune depends on the longitudinal momentum, and chromatic extraction is effected by a $\frac{1}{3}$-integer transverse resonance driven by sextupoles. The micro-bunches have high momenta and are preferentially extracted. The method has been tested at the AGS with a 20 kV, 93 MHz cavity yielding proton bunches 0.3 ns long with 11 ns spacing. However, the 40 ns bunch spacing for TOF implies the use of a 25 MHz rf system, and the 0.15 ns bunch length at this lower frequency is more challenging; moreover, a solution that is economical with rf voltage is required.

Two techniques may be used to further shorten the bunches: (i) a higher harmonic cavity to distort and stretch the rf buckets; and/or (ii) moving the central momentum of the buckets below the extraction threshold, so that extraction takes place from the narrow filament of particles squeezed between the flow-lines of neighbouring separatrices. A variety of single- and dual-harmonic schemes have been simulated using LONG1D; the presently preferred scheme uses fundamental and fourth-harmonic cavities each with 100 kV to produce bunches of width 0.14 MeV and length 0.17 ns (1 second spill) or 0.062 ns (3 second spill) (see Fig. 165). Thus far simulations have included neither collective effects nor the transverse dynamics leading to the betatron resonance. It is proposed to adopt or modify the SLEX code for modelling the resonance, and to include the effect of the impedance upon the longitudinal motion through a wideband resonator model.

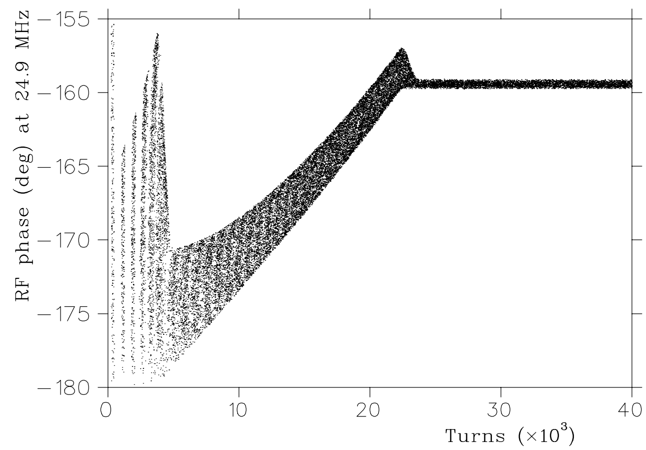

Fig. 165. Extracted proton phase angle versus turns for the first 0.1 s of a 3 s spill, showing the squeezing of the bunch to <0.1 ns.

Space-Charge Compensation with Electron Lenses at the Fermilab Booster

Electron beam lenses have been proposed to compensate space-charge in intense proton beams in the Fermilab booster. In theory, a perfectly matched electron beam can completely cancel direct intra-beam space-charge forces, but detailed tracking simulations are required to confirm the effectiveness of this compensation technique. The ACCSIM particle tracking code has been used to conduct these studies.

It was not expected that a single lens would result in substantial improvements to the booster performance as it has been shown theoretically, and later confirmed with ACCSIM simulations, that too few booster electron lenses (BELs) result in large beta-function distortions. However, good results can be achieved with as few as two BEL elements in the lattice, though for practical reasons three BELs may be required.

ACCSIM was also used to study one of the acceleration schemes proposed by the Fermilab team, in which electron lenses were used to jump across betatron resonances. This was expected to reduce emittance growth, but simulations showed that the non-adiabatic excitation of electron lenses led to beam mismatch, formation of tails, and further particle losses.

Although first results of computer simulations with ACCSIM have not demonstrated significant space-charge compensation with BELs in the existing combined-function lattice, results with F0D0 lattices are more promising. Studies are continuing.

MAGNETS

In addition to contract supervision on the fabrication of the CERN twin aperture quadrupoles described in the CERN Collaboration section, work was carried out on a number of other magnets during this year.

ISAC

Quadrupoles

Sunrise Engineering (BC), using coils from Everson Electric (USA), manufactured and delivered the DRAGON 4 in. and 6 in. quadrupoles. Assembly of the 12 drift tube linac (DTL) quadrupoles was completed; these quadrupoles fit between the ISAC DTL tanks. A trim quadrupole was designed for the ISAC HEBT line and documented in "A design for trim quadrupoles for the HEBT of ISAC" [TRI-DNA-99-5], and "Three dimensional field calculations for the ISAC HEBT trim quad" [TRI-DN-00-19]. The yokes were manufactured by Pacific Design Engineering (BC). The coils were made by Armature Electric (BC). The four magnets have been assembled.

Dipoles

Assembly of the 4 in. and 6 in. x–y steerers for ISAC and the DRAGON facility was completed. Dehnel Consulting Limited (BC) supervised the construction of four ISAC 22.5° HEBT dipoles. Sunrise Engineering machined the steel and did the assembly work. Danfysik A/S (Denmark) made the coils. A 15° switching dipole for beam line 2A has been designed and documented in "Concept Design of the 2A 15° Switching Dipole" [TRI-DN-00-18]. This dipole will allow TRIUMF to send a 500 MeV proton beam to either of the ISAC target stations. Drafting work was nearing completion at year end.

β-NMR Wien Filter

Concept design work started on a Wien filter to spin precess radioactive ions (sodium, potassium, nitrogen, lithium and fluorine) for the β-NMR experiment.

Experiment 614 – TWIST

Design of the steel return yoke for the Expt. 614 superconducting solenoid magnet was finalized in the early months of the year. Quotes were obtained for manufacture of the yoke and the contract was eventually awarded to Axton Industries. An unfortunate breakdown of the large milling machine at Axton Industries resulted in almost an additional two months to complete machining of the 61 tons of steel slabs that comprise the magnet yoke.

The yoke was pre-assembled at Axton Industries prior to shipping the pieces to TRIUMF to allow for inspection and verification of the functionality and tolerances of the assembly. After the large yoke pieces were delivered to TRIUMF and the initial preparations to the M13 experimental area were completed, the yoke was successfully assembled in the M13 area in preparation for field mapping (see Fig. 166).

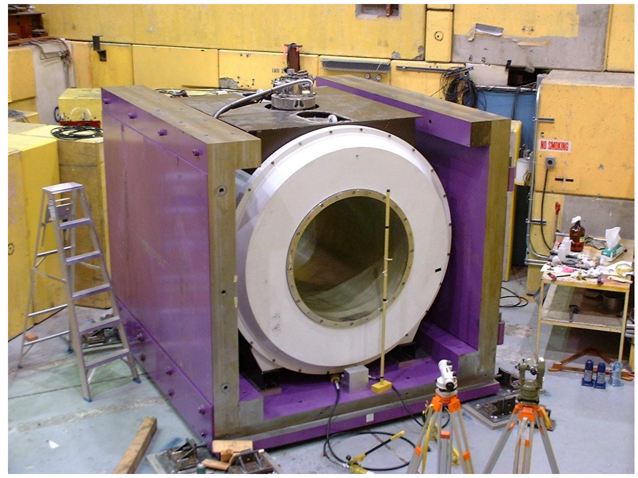

Fig. 166. Photograph of the steel return yoke being assembled around the superconducting solenoid magnet for the TWIST experiment.

Kickers

As mentioned in the 1999 Annual Report, the Kicker group designed a mass separator kicker for ISAC that generates variable pulse widths. The mass separator kicker system includes a pair of deflector plates. One plate is driven by a +10 kV FET based modulator. A –10 kV modulator drives the other plate. Each modulator has two stacks of FETs operating in push pull mode with a variable output voltage and a variable repetition rate from virtually dc to 10 Hz. The specifications for the mass separator kicker demand that a stack of FETs must be held in the "on" state for between 20 ms and 10 s. This relatively long duration required special consideration of component leakage currents and a novel drive technique. The kicker (see Fig. 167) was successfully tested, installed and commissioned. A design note, "Design of ISAC mass separator kicker" [TRI-DN-00-15] and paper, "A FET based mass separator kicker for TRIUMF ISAC project", have been written.

A charge booster unit is required for part of an upgrade to the ISAC facility at TRIUMF. ISAC is presently capable of accelerating only isotopes with atomic mass up to 30. The charge booster will allow ISAC to accelerate all the masses in the periodic table. A fast kicker system is required to study the characteristics of an existing charge booster, designed by ISN (Grenoble), to assess the suitability of using this charge booster at TRIUMF. This fast kicker will subsequently be used in the ISAC facility for TOF separation of the

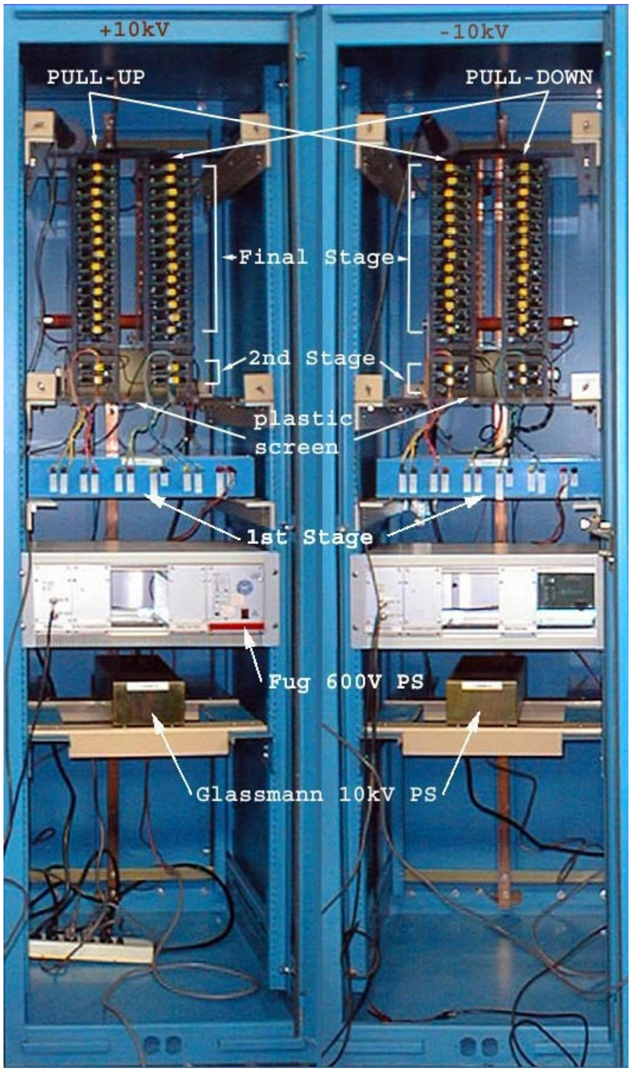

Fig. 167. Mass separator kicker.

chosen charge and to recycle higher and lower charges back to the charge booster, which will increase efficiency from 10–60%. The kicker system includes a pair of deflector plates. One plate is charged up to –4 kV by a FET based modulator, while the other plate is held at ground potential. The modulator consists of two stacks of FETs operating in push pull mode with variable output voltage, pulse width, and repetition rate from virtually dc to greater than 50 kHz. The specifications for the kicker call for rise and fall times of less than 100 ns and a minimum pulse width of 500 ns. The large dynamic range for the repetition rate and pulse width require a novel circuit design and control technique, which also results in a relatively energy efficient kicker system. The design of the kicker system was completed with the aid of PSpice. Assembly of the kicker has commenced, and the kicker will be shipped to Grenoble during January, 2001.

Magnet Measurements

73 magnets were surveyed this year and they are listed in Table XXIX.

Table XXIX. Details of surveyed magnets.

Quantity	Project	Description
1	DRAGON	5 in. x–y steering magnet from CRNL
4	ISAC	DTL triplets (12 quads)
1	TUDA	Long quad from Daresbury
6	TUDA	Short quads from Daresbury
2	DRAGON	4 in. quads
5	DRAGON	6 in. quads
1	DRAGON	Asymmetric 6 in. quad
4	ISAC	HEBT dipoles
24	ISAC	HEBT short CRNL L1 quads
2	ISAC	HEBT long CRNL L2 quads
9	ISAC	HEBT 4.5 in. double steerers
4	ISAC	HEBT $2\frac{1}{4}$ in. trim quads
2	DRAGON	6 in. x–y steerers

MECHANICAL ENGINEERING

Mechanical engineering work at TRIUMF is initiated by the submission of a Request for Engineering Assistance (REA) form which is assessed and assigned according to the size and schedule of the task. Large, complex projects may require a team approach guided by the assigned engineer. Many of the ISAC REAs fall into this category, i.e., target module 2 and 3, ISAC Remote Handling. Some requests were submitted prior to this report period, the work being extensive enough to require several years for completion, i.e., DRAGON, Expt. 614.

There were 35 ISAC REAs submitted during the year. However there were, as well, about 15 REAs carried over from the previous year of which perhaps 5 are long term projects. In non-ISAC engineering, there were 16 REAs submitted plus about 10 carried over from the previous year.

As in the past, in this report period there was continuous participation of engineering personnel in performing engineering analyses, consideration of safety related issues, design reviews and other ad hoc engineering related small jobs.

ISAC

ISAC projects again remained the major effort during the year. The emphasis, however, has shifted away from the target hall and now embraces all aspects of the project. This effort ranged from project management, i.e., DRAGON, to individual design and engineering projects which usually require involvement from design and design review, through manufacture and assembly to installation, i.e., DTL components.

Also during this report period, Engineering, along with ISAC Operations and Remote Handling, produced a list of outstanding issues related to the target hall. This was presented and discussed at engineering meetings later in the year. The list of issues falls under four main headings: modules, target hall, ion source, and hot cell. The intention of this is to consolidate and highlight all tasks that: (a) have not been completed; (b) have not commenced; and (c) are looking for a solution. This was done not only to identify and consolidate, but also to allow for planning and to assign priority, schedule and manpower in order to complete this work. High priority tasks obviously are associated with allowing for continued radioactive ion beam production, i.e., spare components for containment boxes for the target and exit modules. Other tasks have a priority related to increased radioactive ion beam current (up to 100 μA). This task list work is currently being reviewed with the object of assigning priority and establishing a schedule early in 2001, so that manpower can be allocated.

Target hall

The area immediately downstream of both target stations is the location of the 5B diagnostic station which had intentionally remained accessible during radioactive ion beam commissioning. Subsequent to that achievement, Safety requested that shielding be added to fill that volume. To achieve this, the 5B diagnostic box and stand were redesigned with a smoke stack for vertical access and the turbo molecular pump was removed. Steel and concrete shielding blocks were designed to straddle the beam line. These were installed for both the west and east target station. This will reduce the radiation level in the pre-separator magnet/DB0 area, simplifying maintenance.

Design changes were required on the hot cell roof turntable due to unexpected torque required to rotate the large turntable bearing. Conversations with the bearing manufacturer confirmed that the torque was at the high end of what was deemed acceptable for this bearing. Due to the very low duty cycle, however, it was decided that the risk was minimal relative to disabling the hot cell for six weeks while the bearing was returned to the manufacturer for inspection.

It was decided that, manpower permitting, work would commence on the east target station modules – namely the entrance and dump modules. This did not occur due to other work having priority. It is hoped that work can begin early in 2001.

Target module

The 100 μA target module used to house the Talbert high power target in December, 1999, was placed in a storage flask in the target hall subsequent to testing. This unit has now been designated as TM3 and will receive attention after a cooldown period and once TM2 is far enough along in its assembly. Although complete enough to house the 100 μA target, TM3 only required thermocouples; hence the service duct, service cap, and containment box terminations were in an incomplete state (TM3 $\sim$ 65% complete).

Meanwhile TM2, which will be built to support a surface ion source, had many problems associated with the new containment box and service duct design. In the case of the containment box, this was a result of distortion of the sheet metal components during welding and was alleviated by attaching the box to its mounting flange using screws. All flanges were re-made and holes located using a master template.

Completion of TM2 has been further delayed by the decision to provide junction blocks in the containment box so that all services can be disconnected such that not only can a target/ion source tray be removed in the hot cell, but the entire service duct can be withdrawn from the service cap (i.e., in the event of a HV breakdown).

Accelerators

RFQ work from an engineering perspective was essentially completed in 1999.

Engineering support for the RF group continued in the assembly and installation of the DTL linear accelerator tanks and associated triplet magnets, and rf buncher components and diagnostic boxes. It was found, during individual DTL tank testing, that the vacuum tank wall temperature was excessive and the RF group devised a method of fastening cooling tubes to the outer wall that alleviated the problem.

Installation of all DTL components on the support frame was a challenge due to the tight alignment requirements and restricted access. There were numerous problems associated with various components that had to be overcome. However, eventually alignment and stable beam transmission were successfully achieved.

DRAGON

This year, engineering support for DRAGON was equally divided between detailed design, fabrication and installation. While the gas target (start of the DRAGON beam line) was already installed in the fall of 1999, followed by a power supply platform (December, 1999), most of the other beam line components were installed this year.

Electrical installation started in the spring, with construction of an overhead cable tray trunk ($\approx$12 m long) from the north wall of the ISAC hall to the DRAGON power supply platform to carry the main services for DRAGON. First the main ac feeder cables were installed, routed to the main breaker panel and transformers (at the power supply platform) for the DRAGON ac distribution. Installation of the main cooling water headers, air supply, and hydrogen exhaust duct (8 in. diameter) from the gas target to the ISAC hall roof followed in late spring.

Detailed design and fabrication of magnet supports, vacuum components and diagnostics devices were done during the summer months. Also, power supplies under and on top of the power supply platform were installed and connected to services (ac power, cooling water), as manpower was available.

Installation of magnet supports and placement of magnets and alignment began in the fall. During the same period, cable trays and dc cables were installed and connected to most devices and ac power routed along the beam line, followed by installing and connecting cooling services to the devices and installing piping for vacuum roughing and backing lines.

In preparation for the α particle test in January, 2001 (described elsewhere in this report), vacuum components were installed from the gas target to the electrostatic dipole 1 tank (DRAGON legs 1 and 2), i.e., beam pipes, BCM 1 monitor box, charge slits box, magnetic dipole 1 vacuum vessel. Components for the α test (α source holder, wobbler magnet and movable collimator, strip detector mount, etc.) are nearly complete and will be installed in January, 2001.

Fig. 168. DRAGON's ED2 electrostatic dipole during assembly.

The vacuum tanks for the ED1 and ED2 electrostatic dipoles were fabricated and vacuum tested. After thorough cleaning of inside surfaces, they were installed in the beam line and aligned. Assembly of ED1 and ED2 dipoles was done during the summer and fall period (see Fig. 168). Since electrostatic dipoles are expected to be tested up to 230 kV, assembly was a labourious task. All parts were cleaned and polished to a mirror finish and assembly was done in a dust-free temporary cleanroom. Both dipole assemblies were pre-aligned to close tolerances. The ED1 dipole assembly was installed in the vacuum vessel in early December.

Finally, engineering support was provided for various projects including 1A vault quad lifting beam and counter weights, BL2A switching magnet stand and vacuum box, and various support frames for the DRAGON beam line.

Engineering – Other

***G*∅ experiment**

The magnetic field mapper gantry for the superconducting magnet system (SMS) destined ultimately for the *G*∅ experiment at Jefferson Laboratory was delivered to NPL at the University of Illinois (UIUC) in the summer (see Fig. 169). The gantry system will be used

Fig. 169. Photograph of the *G*∅ magnetic field mapper under test at the University of Illinois.

for magnetic field verification of the giant magnet in its actual operating state. After two further trips later in the year by TRIUMF engineers, the gantry system was fully operational and tested in the following areas:

- motion control and dynamic properties,
- position calibration and reproducibility,
- electronics safety interlocks,
- laser target tracking, and
- system control software.

The system has been used extensively by UIUC physicists for interim measurements and development work. Two more trips are needed in the spring of 2001 to finish software development and preparation, and to do the actual SMS magnetic field verification measurements.

M9 solenoid

Ongoing engineering support was provided throughout the year for operation and maintenance of the M9B superconducting solenoid and helium refrigerator.

ATLAS – University of Victoria

The physics activities of the ATLAS group are described in the Science Division section. Here, the engineering support tasks undertaken by the TRIUMF team at Victoria are described.

Hadronic endcap (HEC)

The two main tasks of the group this year have been the design of the assembly equipment for the four HEC wheels at CERN in collaboration initially with CRPP and now with Alberta, and the design and construction of the shipping container for the HEC modules produced at TRIUMF. In addition, the group has provided mechanical engineering support for the HEC group at CERN by providing the services of a chief engineer. This aspect heavily involved the group in planning for ATLAS construction at CERN.

Each of the four HEC wheels is assembled on a table. This table must be raised well off the ground so that the module, once built, can be taken from the assembly table, rotated, and presented to the cryostat. This equipment is being designed at Victoria in collaboration with Alberta. Figure 170 shows the layout of this equipment at CERN.

The design and manufacture of this equipment will be completed during 2001. Testing with dummy loads will commence early in 2002.

The shipping of series modules from TRIUMF to CERN entails shipping 157 tonnes of modules. A cost effective and safe method is required. The plan is to ship by a container outfitted with a frame for the modules that has a spring-damped system. The design, construction, and testing of this container system was finished this year. The container will be used to ship 10 payloads each of about 20 tonnes. Early analysis of the best route showed that the overland route to the east coast of North America and then on to CERN was the cheapest and fastest route. However, this route puts the modules in too much danger of experiencing high g forces, so it is only used for the return journey of our empty container. The chosen route is via the Panama Canal, Antwerp, Rhine barge to Basle, then by Swiss autoroute to CERN. This route has now been travelled twice without tripping the g monitors.

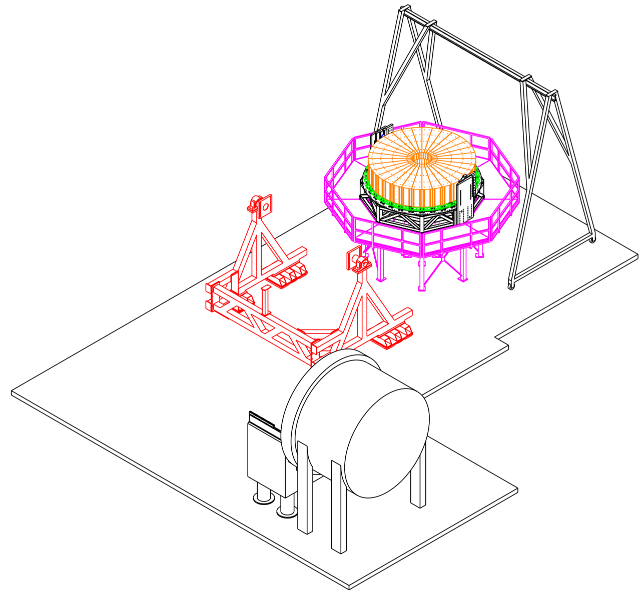

Fig. 170. Early concept of the layout of the proposed HEC wheel assembly equipment in B180 at CERN. All the equipment, except the cryostat and acceptance cradle, shown at the lower right hand corner of the figure, is a Canadian responsibility.

Signal feedthrough project

The signal feedthrough project moved into the production stage in the summer. Procurement of all materials, except the pin carriers, has proceeded without problems. Difficulties, apparently due to variations between batches of rolled steel used for the pin carriers, has caused considerable difficulties with their production in industry. The Victoria group, in collaboration with the ATLAS group at BNL, has been actively pursuing an understanding of and solution to this problem. Some delay in the project completion date is anticipated due to these problems, and it can only be estimated accurately once full production has restarted; it is likely to be in the 3 to 6 month range.

It was always anticipated, once the design of the feedthrough and production methods was complete, that the design team would move on to the design of a warm flange heater plate. This heater plate provides heating for the flange to prevent condensation on the feedthrough. The design and testing of this component was successfully completed this year. Radiation testing of critical components in the heater plate was undertaken at Dubna, in collaboration with the ATLAS Montreal group.

PLANNING

This year the Planning group was involved in planning, scheduling, coordinating and expediting several sub-projects for ISAC; planning and coordinating activities for two scheduled shutdowns (December 22, 1999 – March 8, and August 22 – October 5); and planning some of the CERN collaboration projects (resonant charging power supplies (RCPS) and pulse forming networks (PFN)).

ISAC

Various plans and PERTs were prepared and updated regularly with manpower estimates and analysis to identify critical areas and resolve any problems. ISAC priorities were evaluated and higher priority was assigned to: the consolidation of MRO and essential projects in the target area to increase beam reliability; completion of a hot cell; completion of β-NMR for the first experiment in May, and for the soft landing experiment with the high voltage cage in July.

On the accelerator side, major milestones included: Test #2 (commission MEBT) by February; Test #3 (commission beam from DTL tank 1 including triplet and buncher) by July; and install all DTL systems and accelerate beam to 1.5 MeV/u by December. Manpower planning was done, activities were coordinated and expedited, and the above goals were achieved on schedule.

Technical details and progress on PERTed activities are described elsewhere in this report under the respective principal group. However, following is a summary of the main projects along with the major milestones achieved.

Target areas and hot cells

Extensive work was done to upgrade target areas, target hall crane interlocks and controls, hot cell (improved system for lead glass shielding windows, portable shielding plug, and access doors). Some contamination was experienced while changing a target, which increased the priority of designing a decontamination facility. An alternative conditioning system to expedite the process of changing ISAC targets was designed and fabrication is in progress.

Drift tube linac (DTL) systems

After evaluating the priorities and workload, it was decided to do Test #3 with DTL tank 1, triplet and buncher in June to gain experience and then install and test all DTL systems to accelerate the beam to 1.5 MeV/u in December. One large stand was designed, fabricated and installed in March to support all 5 DTL tanks.

Fabrication of DTL tanks 2 to 5 with stems and ridges was done in July, followed by assembly, rf tests and preparations for installation in the ISAC hall. Vacuum through all DTL systems was achieved by December 15, and a helium beam from the off-line source was accelerated to 1.5 MeV/u on December 21.

HEBT

Due to increased workload, the HEBT project was divided into two parts: HEBT1 (up to upstream of benders to DRAGON and TUDA beam lines); and HEBT2 (all remaining HEBT components). Major jobs included: design, fabrication and installation of vacuum system, beam line hardware, diagnostics, and controls components for HEBT1 to commission beam through all DTL systems. Due to the heavy workload in the ISAC RF group, all rf activities had to be carefully planned, coordinated and expedited. The 11 MHz buncher, chopper and bunch rotator had to be deferred until spring 2001.

Low energy experiments

These included essential modifications to GPS (lifetime), LTNO, yield station, and β-NMR. Extensive work was done on planning, coordinating and expediting activities and critical components from the Machine Shop and outside suppliers for β-NMR, laser polarization systems, spectrometer, and associated LEBT components. The first β-NMR experiment was done in May, followed by installation of the HV cage with associated safety control systems to do a soft landing experiment in July.

High energy experiments

These involved DRAGON and TUDA. Installation of HEBT components up to the TUDA experimental station, with associated services, started with an aim to finish before March, 2001. A special room was designed and constructed for the TUDA detector system electronics, with all services and a special grounding system.

In spite of significant efforts in the Design Office, overall progress on DRAGON was relatively slow due to a lack of technical resources and a higher priority on DTL and HEBT tests. All major components for legs 1–5 were installed by the end of September, and services were connected by December. ED1 and ED2 tanks were installed and electrodes assembled in September, and the tank vacuum tested in October/November. Magnetic dipoles (MD1 and MD2) were installed and the MD1 vacuum chamber was fabricated and made ready for installation.

ISAC-II

PERTs were prepared that included work on specifications and design of a superconducting rf test facility and dummy cavity with an aim to install and test a Nb cavity in summer, 2001 after receiving it from Legnaro.

CERN

The Planning group was involved in planning and scheduling the activities for five 66 kV resonant charging power supplies (RCPS), and nine pulse forming networks (PFN). The assembly and testing area for RCPS and PFN production was designed and constructed with crane and associated services. Several contracts for PFN tanks and other components were awarded to local machine shops.

Shutdown Activities

There were two major shutdowns during the year: the winter shutdown (December 22, 1999 – March 8), and the fall shutdown (August 22 – October 5). Major cyclotron jobs completed in the winter shutdown included: shim plate clearance, 2C work, EX2A, EX1 MRO, ISIS, and rf MRO. Meson hall jobs included: 1AT1 target MRO, 1AM8 cabling, T2 water package MRO, M13 jaws vacuum leak repair, M15 separator vacuum leak, M20 beam blocker repair, M9A rf separator, T1 profile monitor, and BL1A exhaust modifications.

The main purpose of the fall shutdown was to blank off M8B1 to repair a vacuum leak in this area. Cyclotron jobs in the fall shutdown included: jack #2 MRO, duct cleaning in computer and control room, tiles in control room, water systems MRO, and measurements for vault services upgrade (to prepare for January, 2001 shutdown). The lid was raised on September 28 to fix inflector problems encountered during the usual start up.

TWIST (Expt. 614)

The Planning group got actively involved in this project in the second half of 2000. PERTs were prepared with an emphasis on design, fabrication and installation of magnet yoke, detectors, detector cradle, transport cart, field mapper, and other associated components.

DESIGN OFFICE

The ISAC project received 12,325 hours of Design Office time, which is 71% of available hours. The office has been kept very busy preparing conceptual and detailed designs for many different aspects of the project. Specifically, and in order of magnitude, they are: (a) DRAGON electrostatic dipoles, charge selection diagnostics, mass slits, beam position diagnostics, beam line components for vacuum systems, and other mechanical support; (b) HEBT1 and 2, beam line components, support stand systems and diagnostics sufficient to transport beam to DRAGON and TUDA; (c) ITW5B and mass separator DB0 redesign; (d) ECR target design, test box, conditioning system, and target module updates; (e) rf cavities for ME chopper, DTL and HE rebuncher; (f) beam line 2A extraction probe modifications and switchyard magnet design; and (g) TUDA experimental beam line components.

The CERN contribution still received a significant 10% of Design Office time, with most effort concentrated on the pulse forming network and HV switches.

The most significant TRIUMF project undertaken was the Expt. 614 superconducting solenoid for the TWIST experiment. At 9.3%, this included design of the magnet yoke, detector cradle, transport cart, and field mapping device(s).

The demand for photographic and visual art services continues to increase in support of seminars, conferences, and publications, such as the work displayed in the 1999/2000 Annual Financial and Administrative Report and the foyer of the administration building.

MACHINE SHOP

The TRIUMF Machine Shop, with 22 technicians, produced approximately $140,000 worth of fabricated and machined components for various on-site groups each month. Our shop charge out rate is $60/hour. The distribution by TRIUMF divisions and other groups is shown in Table XXX. In addition, 285 separate work packages worth more than $1,030,000 were subcontracted through the Machine Shop to local industrial companies.

Table XXX. Machine Shop utilization.

ISAC	40.6%
Science	21.4%
ISAC Operations	18.3%
Cyclotron	7.1%
NSERC	4.2%
ISAC Development	2.4%
Affiliated Institutions	1.6%
Cyclotron Refurbishing	1.6%
Nordion	1.1%
CERN	1.0%
Accelerator	0.3%
Administration	0.1%

The Machine Shop continued to be fully loaded throughout the year with overtime needed to meet priorities. ISAC continued to be the major user of our services. Early in the year we commissioned a new 5-axis CNC machining centre which has greatly enhanced our machining capabilities.

BUILDING PROGRAM

The year 2000 demanded continued support from the Building department in TRIUMF's endeavour to have the new ISAC beam lines operational within the projected time frame. To this extent we designed and contracted construction for several ISAC projects:

- A radiation shield at the DTL portion of the high energy beam line consisting of a 24 ft long × 12 ft deep × 11 ft high steel column and beam structure with 18 removable composite lead on plywood panels.
- For the TUDA experiment a 16 ft × 12 ft × 9 ft high monitoring cabin was built in conventional wood construction with vinyl coated gypsum panels on the outside and sheet copper clad plywood walls and ceiling inside, together with an electrically conducting floor of vinyl tiles on plywood and sheet copper.
- An 18 ft × 12 ft × 9 ft high facility had to be built outside the east wall of the ISAC experimental hall to store and dispense the various required gases. An explosion proof exhaust fan evacuates volatile gases from this room.
- Adjacent to the gas handling facility a 15 ft × 15 ft × 18 in. thick reinforced concrete slab was cast to accommodate a liquid nitrogen tank.
- A new one piece 9 ft × 7 ft × 12 in. reinforced concrete hatch cover was cast for easier access to the target hall and hot cells.

An extensive renovation of the upper two floors of the biomedical annex was carried out to provide office and laboratory space for the μSR group. This work was started in December, 1999, and was completed in April, allowing the experimental groups to move in. Seven offices were created on the top floor with sufficient space for 20 work stations, and three offices and a laboratory on the second floor. The annex roof was replaced in the fall.

The space requirements for the Applied Technology group dictated the construction of a 34 ft × 7 ft extension to the existing mezzanine floor along the east wall of the meson hall in the accelerator building. This structure is a cantilevered steel frame with metal deck and concrete topping and an enclosure with exhaust for a sandblaster.

Maintenance and repair of buildings on the TRIUMF site has become a more prominent issue as most facilities are now 30 years old. Approximately $25,000 was spent during the year on routine upkeep, such as painting and minor repairs. A new roof on the accelerator building is now our next priority.

ELECTRONICS SERVICES

Overview

It was another busy year for the Electronics Services group. Major upgrades to site communications infrastructure were performed, along with continued support for CERN and ISAC. In the last quarter we got involved with TWIST (Expt. 614) and now have the equivalent of 5 full-time staff members working on this project. Our other main efforts are in PC support, as well as equipment repairs and calibrations. We continue to assist many groups and numerous experimenters on a daily basis.

Technical Support

Technical Support continued its versatile support to over a dozen different experiments and groups during the year. Major jobs included the design and construction of fibre optic link modules for the BOPPIS experiment at BNL, the packaging and wiring of a very complicated rf control box for β-NMR, and PCB layout for MEBT motor drivers, as well as construction of some voltage to frequency modules for sale to Jefferson Laboratory. In June, Technical Support shifted 80% of its efforts to the TWIST experiment. This included layout, packaging and coordinating, and manufacture of the production version of three hundred 16-channel postamp modules.

Experimental and Target Support

Year 2000's involvement was primarily with CERN and ISAC. CERN work involved manufacturing and assembling the control system for the kicker magnets. Assembly continued for the 60 kV PFN system, which included design and assembly of the kicker PCB. ISAC work involved wiring of the kicker assemblies for the integration separators. Support was also started for the TWIST experiment and involved cabling, plus design of the electronics rack system.

Electronics Shop

Highlights of the year were the great demand for cables and intelligent flow-switch control units. The variety of cables produced included delay cables, communication cables, control cables, patch cables, BNC cables, jumper cables, Varian gauge cables, Lemo cables, ribbon cables, VHF cables, extension cables and many others, custom made, along with a variety of modules for ISAC, TRINAT, Controls group, DRAGON, HERMES, and other set-ups. A group of electronics panels and boards was assembled for CERN. Our in-house designed IFS8 flow-switch controllers were needed for every stage of the expanding ISAC beam lines. There are now 80 of these units on site and this has saved TRIUMF over $300,000 in the last 10 years on this item alone. Late in the year a massive job for the TWIST experiment was started. This job entails the construction of 4000 miniature coax cables and will continue until April, 2001.

Electronics Repair Shop

As usual, the Electronics Repair Shop has been very busy this year – especially with the demand to refurbish numerous pieces of electronic equipment recovered from Chalk River for use in the experimental program here. In total, 281 pieces of electronic equipment were given checkout to confirm functionality, repaired, and/or recalibrated. This included: 19 terminals, 71 monitors (46 colour units and 25 monochrome), 13 SCSI devices, 74 power supplies (which included 27 NIM devices, 11 CAMAC devices, 19 high voltage units, and 17 generic types), 54 nucleonics modules (of which 25 were NIM and 29 were CAMAC), 14 test equipment devices, and 36 miscellaneous electronic devices.

High Level Software Support

For CERN, a system was developed to measure special capacitors for the kicker work. ISAC had a number of motor systems installed for MEBT, HEBT and designed for DRAGON. For ISAC-II, the charge booster measurement was worked on. Site support went to the PIF motor control system, BL2A extraction probe software upgrades, as well as solving problems with the M15 and M9 separators. LTNO received software support, as well as assistance in replacing the computer controlled rf source. For TWIST, the magnet measurement system as well as the wire chamber measurement system were worked on.

PC Support – Hardware

This year brought a significant increase in end user support. The number of consultations and evaluations increased by 150% to about 875 incidents. PC hardware repairs increased by 11% to 300 occurrences. New PC configurations and old PC rebuilds increased 37% to 55 units. Major tasks performed in 2000 included: migrating the Windows virus protection software from Norton AntiVirus to McAfee Virus Scan, defining a new network interface card as a TRIUMF standard, and implementing recommendations for Notebooks. A method was created to efficiently distribute and control Windows software at TRIUMF. User support was enhanced by keeping the PC Web site up to date. It is estimated that there are over 400 PCs in use on the site.

PC Support – Systems

During 2000, the TRIUMF PC backup service design and testing was completed, although problems with throughput across the site held up implementation. The problem was corrected, deployment continued and a tape autoloader purchased to increase capacity. A Web site was created with service information and policies available, as well as an application form for user sign-up. Posted backup schedules and results are forthcoming. The NetWare 3.x servers are being backed up regularly, and several dozen users are on the schedule so far. The service has been in production for several months.

A network server upgrade has been in the planning and testing stages for several months. The Design Office and trailer Gg seven-year-old NetWare 3.x servers are being upgraded and consolidated into one NetWare 5.1 server. The server hardware and software has been purchased, deployment scenarios have been planned and migration and configuration tests are being performed. This major upgrade is analogous to a user upgrading from DOS to Windows 2000. This server will service a majority of the Accelerator Technology division, with a few extra groups from other divisions.

Communications Support

Communications Support had the busiest year in 10 years due to massive network cable upgrading. Most of the work involved new 100 Base-T cables. The main office building had 150 cables installed, biomed got 60, trailers Gg and Rr had 90, and trailer X got 22. In addition there were about 35 other cables installed around the site. Other improvements included fibre optics installation to trailer Gg, biomed, as well as repairs in ISAC. Communications also assisted in the cable installation for the ISAC PA system. Ongoing maintenance included a speedy recovery from the January 10 lightning strike that required replacement of multiple transceivers all over the site that had failed. Documentation is now routinely updated and posted on the TRIUMF Web page for easy reference.

ELECTRONICS DEVELOPMENT

This year again, the majority of the group's effort went into support of the ISAC control system design and installation, and the CERN collaboration. Between February and June, one BCIT co-op student was supervised.

ISAC Support

A Gauss-meter module was designed for readout of Hall probes on the HEBT dipole magnets and the

DRAGON beam line quadrupoles. It is based on the ADPS 2861 DSP chip and can be read via CAN-bus and RS232. A prototype module was built and tested in the lab. The major source of error was found to be the temperature sensitivity of the sensor offset voltage. This was corrected by the module software. Testing will be conducted in February, 2001, to establish resolution and stability of the measurements under actual operating conditions.

On the high voltage power supply for the DRAGON electrostatic dipoles, testing of the Cockroft-Walton 300 kV stack continued. Connector breakdown difficulties plagued the project during the first part of the year. Using a modified automotive spark plug solved the problem. Both a positive and a negative stack were tested successfully at their nominal operating voltage of 200 kV for 30 days. Further design was undertaken to modify the Glassman driver supplies for conditioning of the dipoles.

The group assisted in design and fabrication of the ISAC low energy chopper. Several PCBs were designed, assembled and tested: FET driver cards, fibre optic drivers and receivers, and controllers.

Design and construction commenced on a chopper for the charge state booster. This design is a modified version of the ISAC low energy chopper. Four PCBs were designed, assembled, and tested: FET driver, pulse generator/first stage driver, power supply filter, and an interlock module.

Several specialized CAN-bus controller modules were designed and built. A module with bipolar DAC was designed and used for the etalon position controller and the birefringent filter of the laser system for the β-NMR experiment. Also for β-NMR, a fibre optics board was developed for control of three Bertan high voltage supplies which are located on the experiment's platform. This board allows the CAN-bus to cross a galvanic isolation.

Also for the β-NMR laser system, a piezo positioner was developed for controlling cavity depth on the laser.

CERN

A project to develop a data acquisition board (DAB) for the LHC beam orbit system is described in the CERN Collaboration section. This project occupied three members of the Electronics Development group throughout the year.

Miscellaneous

Experiment 497 – parity

An ADC/averaging module was designed and built. This VME module digitizes and sums signals from the TRIC chambers. It was successfully tested during beam runs in July and December.

M9 vacuum system

After several failures of the PLC processor memory and PLC programmer, it was decided to replace the obsolete Modicon 884 processor. It was replaced with a remote I/O adapter and the system was integrated into the beam line 2A Modicon Quantum PLC system. This solution retains full use of all existing I/O modules. The needed re-write of the ladder logic software was made, conforming to the ISAC standard. Changes were completed and tested during the fall shutdown. EPICS screens for a graphical user interface have been prototyped.

For the ISAC β-NMR experiment, two VME modules were developed at fairly short notice. They interface to a commercial rf synthesizer and allow fast steerage of the β-NMR rf program.